Item No. 001A0

Technical Progress Report

Development of a Low Noise 10 K J-T Refrigeration System

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1.0 Introduction

This report summarizes work done on Contract No. N00014-86-C-0301 during the period October 15 to December 1, 1990 on the development of a low noise Joule-Thomson, micro- miniature refrigeration system.

Work has continued on the evaluation of the pneumatic compressor system which will be used to demonstrate 1) operating lifetime of the refrigerator gas compressor under development and 2) compressor-refrigerator system performance. Work to improve the cooling capacity of the refrigerator at 20K by using more efficient heat exchanger designs has continued. While operation down to 20K has been achieved and reliably reproduced, the investigation of the use of thinner glass slides and metal foils as the interlayer in the heat exchanger suggests that substantial increase in the exchanger efficiency can be achieved. This work is also being utilized to enhance the performance of the heat exchanger section of the third stage of the refrigerator, the helium stage.

Results of work done under this contract were reported in a technical paper at the International Cryocooler 6 Conference in Plymouth, MA in October 1990. A paper discussing improvements in the application of mixed gases to J-T coolers and reporting work done in this area as part of this contract will be reported by MMR at the Cryogenic Engineering Conference in Huntsville, AL in June 1991.

2.0 Compressor: Pneumatic Operation

The relative merits of using various gases (air, Freon 22, Freon 14, and Freon 13) as the working fluid of the pneumatic compressor were reviewed in previous reports, Line Item Nos. 001AM and 0001AN.

A lightweight, compact, oil lubricated pneumatic compressor capable of operating with an input pressure of 4 atm. and an output pressure of 14 atm to drive the refrigeration gas compressor has been completed using Freon 13. This low gamma working fluid, in combination with improvements in the controlled air flow directed over the housing of the pneumatic compressor, produced a steady state housing operating temperature below 65° C. This is a very acceptable temperature. These results will enable the program to progress to the phase of long term operation testing of the refrigeration gas compressor.

2.1 Refrigeration Gas Compressor

This compressor has been modified to incorporate new seals and guide rings. The seals utilize a newly developed material which is better matched to the pressure and piston speed parameters of this compressor. The guide rings are of the same material as the seals and have been incorporated into the design to center the piston in the compressor cylinder. The "centering" provided by these rings will reduce seal wear previously associated with misalignment of the piston and the compressor cylinder.

3.0 Filter: Purging Criteria

Refrigerator operating lifetime is strongly dependent upon gas purity. Stringent performance requirements have been placed on the filters used with this compressor-refrigerator system to ensure a continuous supply of high purity gas. Filter assembly and purging criteria have been established and refined. These procedures must remove moisture, trap hydrocarbons and remove any gases, such as nitrogen or oxygen, which could freeze out at temperatures below 65K. Activated carbon filtration is

being combined with the zeolite filter technology presently in use. Using gas drawn from storage tanks with gas purity as low as 20 parts per million, filtered gas purities as low as 80 parts per billion have been achieved.

4.0 Refrigerator

Difficulties had been reported previously in operating some of the refrigerators to their minimum temperature. This appeared to be due to inefficiency of the final stage laminar flow heat exchanger in the hydrogen refrigerator. This inefficiency is strongly dependent upon the mass flow through this stage and on the thermal conductivity of the interlayer which separates the two counter flowing gases in the heat exchanger. At low temperatures, the thickness of the interlayer becomes important because the rapid drop in thermal conductivity of the glass, as the temperature is reduced, creates an unacceptably large temperature drop across the interlayer. The use of a very thin glass slide or a higher thermal conductivity material, such as metal foil, as the interlayer in the heat exchanger has been investigated and tested. Details and results of work in this area are reported below.

4.1 Fabrication

Refrigerators have been fabricated using six mil and three mil (instead of the normal 10 mil) glass interlayers to address the inefficiency in the hydrogen stage which lies in the temperature drop across the interlayer between the inflow and the outflow channels.

Characterization of the bonding process to be used with platinum foil has continued. Good clean bonds of the platinum to the solder glass have been obtained. Efforts to refine this approach for the fabrication of the refrigerators will continue .

Results of this work will be applied to the heat exchanger of the third stage of the refrigerator as well since the drop (as temperature is reduced) in thermal conductivity of glass is large in the 20K to 4K temperature range.

4.2 Test Results

The refrigerators fabricated with thin glass interlayers have evidenced some structural problems in the form of cracking and crazing. The temperatures and duration of the fusing process must be adjusted to accommodate the use of these thinner glass interlayers which are much more sensitive to stress and differences in the coefficients of thermal expansion than the thicker interlayers appear to be. Testing has continued in order to document the proper sealing criteria for glass slides of thicknesses less than ten mil. With the use of extremely thin glass slides as interlayers, there is some evidence of portions of these slides collapsing into the gas channels below. Although this slumping is limited, its effect on the flow cross section of channels of shallow depth is measurable and can significantly affect the flow of gas through the refrigerator. Work is proceeding to develop the proper firing profile for these thin glass slides which will eliminate or minimize this slumping problem.

Two-stage refrigerators are being retested and temperature data is being collected at various points along the heat exchangers. These measured results will be compared with the temperature profile prediction of the computer model for the refrigerator. It is believed that the rapid change with temperature of density, conductivity, and viscosity of hydrogen and the associated changes in the Reynolds and Nusselt numbers at temperatures below 60K must be modeled in greater detail. Work on the modification of the computer model is underway to accommodate the introduction of such rapid parameter changes.

4.3 Future Refrigerator Design Objectives

As discussed above, we are continuing work on the use of still thinner glass and thin metal foil interlayers in the hydrogen and helium stages of the cooler. This is key to the efficient operation of the low temperature stages of the refrigerator. It is expected to increase the efficiency of the present hydrogen cooler by a factor of three and is the essential step, as well, in the attainment of adequate cooling capacity at liquid helium temperatures. We are continuing the life testing of the compressor and the development of better gas filtering technology for use with the refrigerator.

5.0 Personnel

The following persons have been involved in the program:

Program Management and Supervision
W. A. Little
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Refrigerator Fabrication
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Respectfully submitted,

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